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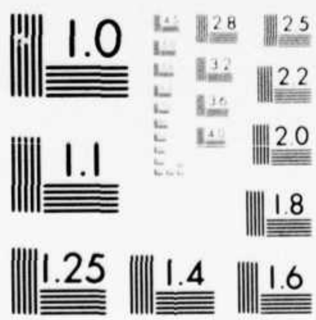

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THE IDENTIFICATION AND APPLICATION OF USAF BASE LEVEL SUPPLY SYSTEM MANAGEMENT INDICATORS

Charles M. Johnson, Captain, USAF
James L. Vick, Captain, USAF

LSSR 6-77B

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NORS rates are used to evaluate the effectiveness of the USAF base level supply system. This thesis critiques the use of NORS rates and other management indicators used by USAF managers in evaluating supply system performance and proposes new management indicators. USAF inventory policy is examined and the EOQ item, recoverable item, and engine inventory models are analyzed. Each model's variables, assumed demand distribution, implied performance level, and constraints are reviewed. Indicators are proposed that will provide managers with information with which to ensure actual variable values do not exceed their constraints. The proposed indicators will provide a method for evaluating and controlling base level supply system performance. Although a management indicator that directly measures the relationship between supply system performance and operational capability cannot be developed, the proposed indicators will minimize backorders. RAND has shown that by minimizing backorders, the NORS rate is also approximately minimized. Additionally, NORM should be reduced when backorders are minimized. While some computer programming changes will be required, no changes to USAF inventory policy will be necessary to use the proposed indicators.

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THE IDENTIFICATION AND APPLICATION OF USAF BASE LEVEL SUPPLY SYSTEM MANAGEMENT INDICATORS

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

Charles M. Johnson, BS
Captain, USAF

James L. Vick, BS
Captain, USAF

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This thesis, written by

Captain Charles M. Johnson

and

Captain James L. Vick

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

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DATE: 7 September 1977

John M Pearson

COMMITTEE CHAIRMAN

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CHAPTER I

INTRODUCTION

Overview

United States Air Force (USAF) base level supply system decision making has become increasingly difficult as the complexity and cost of defense resources have grown. Managers monitor more and more activities and make more and more decisions regarding those activities. Headquarters (HQ) USAF must precisely define system objectives and provide the methodology whereby the system can be organized to achieve those objectives.

The methodology should provide both a means of evaluation and a means of control. For simplicity of operation, the methodology should be translated into standards that are both targets for management efforts to be aimed and measures of the accuracy of those efforts. The standards must be reasonable. They should not be set so high that no one will strive to achieve them or so low that they do not present an achievement challenge. The standards must be understandable and stated such that no individual is unclear as to the level of performance demanded. The standards must support USAF objectives (31:43-44). Finally, the standards must be relatable to performance

in order to provide management with meaningful decision-making information. This relationship is expressed through the use of indicators. An indicator is ". . . a piece of essential information about performance, often expressed in terms of a ratio or relationship [31:50]."

Definition of Terms

a. Automatic Resupply and Building Time (ARBUT)--

> This phase covers the submission of notification by the base of a depot overhaul generation requiring resupply, receipt, [and] buildup of a serviceable engine ready for installation [45:A-].

b. Bachelor Item--"An item that has no interchangeable relationship to another item [47:1-9]."

c. Backorder--"An obligation, assumed and recorded by any supply echelon, to issue at a subsequent date a requisitioned item which was not immediately available for supply [47:1-9]."

d. Base Maintenance Removal Interval (BMRI)--

> . . . the ratio of the forecast fleet flying hours per base maintenance removal. The BMRI is computed by dividing the forecast flying hours in a given period of time (usually a 3 month period) by the simulated base maintenance removals for that period. The BMRI is published quarterly for each engine model in the Actuarial Removal Table [45:A-1].

e. Base Repair Cycle--"This phase extends from the removal of a reparable engine until it is ready for installation at the base [45:A-1]."

f. Cannibalization--

The authorized removal of specific components from one item of AF property for installation on another item of AF property to meet priority requirements with the obligation of replacing the removed component [47:1-11].

g. Daily Demand Rate (DDR)--". . . the average quantity used daily [49:11-3]."

h. Expendability, Recoverability, Repairability, Category (ERRC) Code--"Either a single digit or three-digit supply oriented code used to classify AF items of supply into various categories for management purposes . . . [47:1-21]."

i. Fill Rate--". . . the ratio of the number of units issued over a fixed time period to the number demanded over the same period [4:v]."

j. Issue Effectiveness Rate--"Percentages are computed by dividing line items issued plus line items backordered into line items issued [49:24-284]."

k. Not Operationally Ready-Maintenance (NORM)--". . . a condition status of material indicating that it is not ready to perform any of its missions because of organizational or intermediate level maintenance requirements [53:3]."

l. Not Operationally Ready-Supply (NORS)--

. . . a condition status of material indicating that it is not operationally ready, because maintenance required to clear a NORM condition cannot be continued due to a supply shortage [53:3].

m. NORS Rate--The ratio of NORS time to possessed time.

n. Not Reparable This Station (NRTS)--

> A status condition determined during shop processing of an item. It indicates that the item cannot be repaired at base level due to lack of authorization, technical skills, parts, facilities, manpower, or any other reason [44:6-8].

o. NRTS/Condemned Quantity--"The number of units required for the NRTS/condemnation processing time [52: IV-19]."

p. Order and Shipping Time (O&ST)--

> The time interval between the initiation of stock replenishment action for a specific activity and the receipt by that activity of the material resulting from such action. Order and shipping time is applicable only to material within the supply system and is composed of two elements: (1) Order Time--the time interval between submission of a requisition or order and shipment of material by the supply activity; (2) Shipping Time--the time interval between the shipment of material by the supplying activity and receipt of material by the requiring activity [51:2].

q. Order and Shipping Time Quantity (O&STQ)--". . . is the quantity required to be on hand to meet demands during the period represented by the order and shipping time [49:11-3]."

r. Overhaul Removal Interval (OHRI)--

> . . . the ratio of the forecast fleet flying hours per overhaul removal. The OHRI is computed by dividing the programmed flying hours for a specific quarter (based on the HQ USAF Program Auth) by the simulated overhaul removals. The OHRI represents the number of flying hours expected to accumulate on all engines (TMS) before a removal for overhaul is experienced.

The OHRI for each engine model is published quarterly in the Actuarial Removal Interval Table. The OHRI may be computed with or without maximum time consideration [45:A-3].

s. Percent of Base Repair (PBR)--"Percent of units repaired of those processed through the repair cycle [52:IV-18]."

t. Ready Condition--

> . . . capable of safe use and the minimum number of subsystems designated by a Military Department as mission essential, are installed and operable for the performance of one or more of the primary missions [53:3].

u. Recurring Demand--"A request made periodically or anticipated to be repetitive by an authorized requisitioner for material for consumption or use or for stock replenishment [47:1-37]."

v. Reorder Point Quantity--

> (1) The minimum quantity required to be on hand and on order to enable stock replenishment with low probability of depletion of the safety level; (2) the quantity to which on hand and on order asset quantities are compared to determine the need to order; (3) the sum of the repair cycle requirement, order and shipping time requirement, safety level, and special levels [51:3].

w. Repair Cycle Time (RCT)--"Average repair cycle days computed over a total of five quarters [52:IV-18]."

x. Repair Cycle Quantity (RCQ)--

> . . . the number of units that must be stocked to meet demands during the repair cycle. In brief, this quantity varies according to the success of the base repair program. The computation of the repair cycle quantity requires the determination of average percent of past repair and the determination and/or application of the repair cycle time [49:11-3].

y. <u>Safety Level Quantity (SLQ)</u>--". . . the quantity required to be on hand to permit continuous operation in the event of minor interruption of normal replenishment or unpredictable increases in demands [49:11-4]."

Background

Department of Defense (DOD) Instruction 7730.25 requires that quantitative standards be established for weapon systems and designated mission essential material to measure material readiness, maintenance and supply effectiveness and to identify and correct the causes of excessive downtime (53:1). The standards are to be based on "engineering predictions, evaluations of tests and demonstrations, economic analysis, empirical logistic support data or mission requirements [53:2]." Individual standards are required to be established for each type, model, and series (TMS) where there are significant differences within a model. The standards established are to be viewed as performance targets for support activities. Material readiness is required to be compared to the standards at least quarterly to ensure that effective support is being rendered. Periodically, the standards must be reviewed and adjusted as necessary (53:2).

Use of the terms Not Operationally Ready-Supply (NORS) and Not Operationally Ready-Maintenance (NORM) is required by DOD Instruction 7730.25 to

> . . . categorize the causes for material not being in a ready condition, to give an indication of maintenance and supply effectiveness and to provide data on multi-mission material that has a limited capability [53:3].

The USAF has further categorized NORS and NORM to describe the type of end item and its degree of limitation (46:2-2).

NORS rates are used to determine the percentage of the time that material is not in a ready condition due to a supply shortage. They are also used as a measure of supply system effectiveness. Further, NORS rates are used to judge the impact of supply system shortages on operational capability (3:22; 8:1; 56:10). If a particular system's NORS rate is within organizational standards, the supply system is considered to be functioning effectively. If the NORS rate exceeds the organizational standard, the supply system is not considered to be operating effectively and operational limitations are expected to result (22). In "Lessons Learned by an Old Supply Officer," Colonel Steven L. dePyssler states:

> THE MOST IMPORTANT STATISTIC IS NORS AND CANNS [Cannibalizations]. As a CSUP [Chief of Supply] you can be excused for many things but a high NORS and/or CANN rate is inexcusable. That is your PRIME MISSION [15:4].

Although DOD Instruction 7730.25 requires that quantitative standards be set as targets for support activities, HQ USAF does not currently have NORS rate standards (21; 55:4). A 5 percent standard for aircraft grounded due to supply shortages, NORS-G, is used as a rule

of thumb by the Air Force Logistics Command (AFLC) (14; 15; 23). Although no written directives citing a 5 percent standard could be found, briefing slides for the AFLC commander highlight a 5 percent NORS-G rate (23). AFLC does not use differing standards by aircraft or equipment type (23). Tactical Air Command (TAC) Regulation 67-4 establishes TAC NORS standards. While almost all TAC aircraft have a 5 percent NORS-G standard, some, e.g., the RF-4C, have a 4 percent standard (16). The Strategic Air Command does not have fixed NORS standards, but computes the mean NORS rate by aircraft type and then scrutinizes bases with a rate higher than two standard deviations above the mean (32).

While NORS rates do provide information as to the percentage of time aircraft or equipment were not in a ready condition, several problems have been experienced when using NORS rates as management indicators on which to base current and future action.

1. There is no method for evaluating the impact of NORS on operational capability (22; 55:15-16). During fiscal years 1972 and 1973, the USAF asked Congress to reprogram funds to reduce the impact of NORS on operational capability. Congress approved the USAF request and asked the General Accounting Office (GAO) to determine the results of the reprogramming in terms of reducing NORS and its effect on operational capability. GAO found that

operational capability could not be evaluated in terms of NORS alone. Additional factors, such as personnel, equipment and supplies, NORM, and training were also found to affect operational capability. In addition, no significant correlation could be found between the expenditure of the reprogrammed funds and the NORS rate (55:1). Even if the other factors affecting operational capability could be discounted, NORS rates do not significantly correlate with operational capability. An example, while perhaps extreme, illustrates the problem. Consider a base possessing a single aircraft. The aircraft can be NORS-G for one hour each day and still maintain a NORS-G rate of less than 5 percent. If the aircraft is scheduled to fly during the hour it is NORS-G, the sortie will not be flown and the sortie rate will be zero. Conversely, the aircraft can be NORS-G for twenty-three hours each day and still be ready for a sortie, if the part is available in time for installation and the sortie duration is short. While the NORS-G rate for the aircraft is over 95 percent, the sortie rate is 100 percent. A recent study found no significant correlation between the NORS-G rate and the sortie rate (1).

2. NORS rates cannot be accurately explained by issue effectiveness rates. Issue effectiveness is a secondary measure of supply support used by the USAF. Issue effectiveness is the ratio of the number of line items issued over a fixed time period to the number demanded over

the same period. Issue effectiveness differs from fill rate in that issue effectiveness portrays line items issued rather than units issued (49:24-283). Dawley and Feicht examined the NORS rate and seven types of supply issue effectiveness rates at ten operational USAF bases. No significant relationships were discovered (7; 8). Another example will illustrate this point. Again, consider a base possessing a single aircraft. If a customer requests one-hundred line items and ninety-nine of the line items are issued from stock and one line item is backordered, a 99 percent issue effectiveness rate is achieved. The one item that is backordered may result in a NORS condition that lasts for several weeks. While the issue effectiveness rate would be 99 percent, the NORS rate would be 100 percent. Conversely, the customer might receive sixty line items and have forty backordered without incurring a NORS condition. In this case, both the NORS rate and the issue effectiveness rate would be lower.

3. NORS rates do not readily identify causal factors (22). The following example will illustrate the problem. While items should not be backordered as NORS if they can be repaired at the base level, it can happen (32). A NORS condition could occur because skilled maintenance personnel who could locate and correct malfunctions in items with otherwise big percentages of base repair were not available. The problem could be further

aggravated when the items were returned to the depot for repair. Since the base supply spare asset level would have been computed using the high base repairability of the item, the stock might not be sufficient for the increased resupply time.

4. NORS rates cannot be evaluated to determine the effect of changes in system variables (demand rate and resupply time) (22). The effect of increased demand rates cannot be evaluated in terms of NORS. If the demand rate for an item increases, the change in the expected NORS rate cannot be calculated. Only with great difficulty could one even intuitively predict the effect upon NORS of an increased demand rate. Maintenance personnel may be able to repair all of the removed items. A NORS condition cannot be verified as long as the items can be repaired (47:2-6). The probability of not having a serviceable item will increase, because, without a decrease in repair cycle time, spares will be used more quickly than they were being used prior to the increase in demand. An increase in the demand rate can also cause an increase in the NORS rate. If maintenance personnel cannot repair an essential item at the base level, the base stock will be depleted and NORS will occur. Similar examples could be given for the resupply time variable. The NORS indicator cannot be used to predict effects on mission capability.

5. NORS rates cannot be used to assess risks associated with decisions affecting system variables (22). The risk to operational capability incurred as a result of management-directed system variable changes cannot be measured with the NORS indicator. NORS rate calculations cannot indicate the effects of system variable changes and, thus, do not permit managers to evaluate the associated risk to operational capability. Even if a relationship between system variables and NORS could be discovered, there is no means to calculate the direct impact of NORS upon operational capability.

6. Spare asset levels are based upon implied performance criteria (22). For example, spare engine levels are computed using the methodology provided in Air Force Manual (AFM) 400-1 (45). This methodology is designed to ensure a stated probability of incurring backorders.

Several attempts have been made to design supply system management indicators related to operational capability. Usually a NORS rate approach is taken. The GAO recommended that the USAF develop NORS standards based upon aircraft age (55:2). AFLC recommended that HQ USAF adopt the Variable NORS concept (17). Variable NORS is a method of computing NORS rate standards by assigned location for each aircraft TMS, based upon weights assigned to military worth, degree of dispersal, and age. Aircraft are rank ordered in importance and a weight is assigned to

each type of aircraft. Another weight is assigned, based on the number of each type of aircraft at the possessing base. The last weight is assigned, based on the age of the aircraft or the period since a major modification was performed (17; 24). HQ USAF is now studying the feasibility of a variation of Variable NORS called Dynamic NORS (14).

SAC has an additional NORS indicator--NORS commodity hours. NORS commodity hours are accumulated against each NORS requisition (49:6-82). The standard method of computing NORS rates does not reflect the number of NORS requisitions for parts that have been placed for an aircraft. The NORS rate is computed based upon the number of hours the aircraft is possessed and the number of possessed hours the aircraft is NORS for at least one part (34:8). The NORS commodity hours indicator totals the hours an aircraft is NORS for each requisition. Maintenance cannibalizations from a NORS aircraft, made to prevent another aircraft from accumulating NORS hours, are reflected by the NORS commodity hours indicator. The NORS aircraft's additional NORS hours would not be reflected by the traditional NORS rate (36:A-B).

As previously indicated, issue effectiveness is a secondary measure with which to evaluate the supply system (35; 49:26-268). Issue effectiveness suffers from at least two limitations. First, it is difficult to relate

issue effectiveness to operational capability (4:v). Secondly, issue effectiveness rates do not consider the duration of backorders (30:1). A previous example, comparing the NORS and issue effectiveness rates, clearly illustrates both these shortcomings.

A new methodology for developing supply system management indicators is needed. The indicators developed should meet the following criteria:

1. Supply system indicators should be relatable to operational capability. For example, the model used to calculate spare engine levels provides for the probability that at least one aircraft will not be available for operational requirements because a spare engine is not available.

2. The indicators should identify the causes of changes in supply system performance. Any system variable adversely affecting supply system performance should be identified. For example, base spare engine levels are computed using expected values for the following system variables: the overhaul removal interval, the base maintenance removal interval, average base repair time, average depot resupply time, and average flying hours (45:2). When one or more of these variables change without a balancing change in some other system variable, the probability of incurring at least one backorder will also change and system performance can either increase or

decrease as a result. If the relationship between these variables and performance is known, then the variable causing the problem can be identified.

3. Effective supply system indicators should allow an evaluation of a change in one or more of the system variables. Effective indicators should not only allow identification of variables which are adversely affecting operational capability, but also permit the evaluation of the expected effect on operational capability of any changes in system variables.

Statement of the Problem

The GAO has criticized the USAF for not using meaningful logistics indicators (55:16). The problem is that the USAF does not currently use supply system indicators that directly measure the relationship between supply system performance and operational capability. Moreover, the NORS indicator used to measure supply system effectiveness is not calculable in terms of system variables. Although an indicator cannot be designed to directly measure the relationship between supply system performance and operational capability, indicators that correlate with operational performance and that are calculable from system variables can be developed. Such indicators would permit managers to both evaluate the impact of their decisions on operational capability and measure the impact of spurious system changes. The identification and consciencious use

of effective supply system indicators would improve management decisions at all levels in the supply system.

Objectives

The objectives of this study are to demonstrate how meaningful supply system indicators can be developed from current supply system methodology and to indicate how these indicators can be used to evaluate and control supply system performance.

Scope

The computational procedures in AFM 67-1 (49) and AFM 400-1 for determining spare asset levels will be analyzed to determine the methodology employed in their construction. It will then be demonstrated how these methodologies can be used to control and evaluate base level supply system performance. While research will be concentrated on base level supply system management, the techniques will be effective in aiding managers in other logistics areas.

Research Question

What supply system indicators existing within current USAF supply methodology can be used to control base level supply system performance and evaluate the impact of decisions affecting supply system variables?

CHAPTER II

METHODOLOGY

The methodology for the research will consist of seven steps:

1. Locate in AFM 67-1 and AFM 400-1 the spare asset inventory models for supplies and engines.

2. Determine the type of models being used by comparing them with models in inventory literature.

3. Identify the variables and parameters of the models.

4. Identify the type of underlying statistical distributions used to describe demands in the AFM 67-1 and AFM 400-1 models.

5. Illustrate the computation of spare asset levels using the AFM 67-1 and AFM 400-1 models.

6. Demonstrate how variation in variable values affects the computed levels and degree of expected support.

7. Explain how variables can then be used as indicators to evaluate and control the base level supply system.

CHAPTER III

USAF BASE LEVEL INVENTORY POLICY

Base level system inventory policy is established by HQ USAF and is implemented through the publication of USAF manuals and standardized computer programs. Base level logisticians are not authorized to unilaterally change USAF policy. It is their responsibility to carry out policy established by HQ USAF.

The three inventory models used in the base level supply system are the Economic Order Quantity (EOQ) item, the recoverable item, and the engine. The EOQ and recoverable item models are used by the Standard Base Supply System (SBSS). In fact, all SBSS computers are programmed by the Air Force Data Systems Design Center (AFDSDC) with standardized programs directed by HQ USAF (50:2-3; 52:IV-13). The engine model is used by the Propulsion Unit Logistics System (D024) (45:6-1; 52:IV-13).

The SBSS inventory models are based on DOD models (51; 54). While USAF inventory policy is established by HQ USAF, a group entitled the Chapter 11/17 Work Group, after Chapters 11 and 17 of AFM 67-1, Volume II, Part Two, is responsible for studying, evaluating, and recommending changes to USAF inventory and repair cycle asset control policies (42:5; 52:IV-13).

The base level supply system encompasses more than just the base supply squadron. Base level maintenance activities also comprise a major segment of the system. In fact, the base supply squadron depends upon base maintenance activities for the resupply of a portion of the repairable items used at the base level. In addition, most if not all base activities are, at a minimum, customers of base supply and, therefore, a part of the system.

Base level supply system policy is executed through the use of inventory models. A model has been defined as ". . . a representation of a system under study . . . in which the system is represented by symbols that can be manipulated by using mathematical rules [20:13]." The symbols in an inventory model are its variables. USAF inventory policy determines when an item will be stocked and in what quantity. Time and quantity are variables and are "*subject to control,*" thus, they are "*controllable variables* [20:8]."

USAF inventory models have an implied performance level--a given probability of not observing a backorder in a random observation during the reorder interval for the EOQ item model or at any time for the recoverable item and engine models. For a base level manager to intelligently work toward the implied performance level he must understand the operation of the models.

Backorders can result in NORS or NORM and thus are a wider criterion of the supply system's impact on operational capability than NORS alone. As previously stated, NORS cannot be declared if a backorder can be satisfied through the repair of a base asset. The GAO has highlighted the fact that NORM rates are often three times as high as NORS rates. While backorders are just one of the many factors that affect NORM, the impact of backorders is significant (55:16).

The EOQ Item Model

The EOQ is the lot size which results in the least total variable cost, i.e., the minimum sum of ordering cost and holding cost (27:226). The USAF applies the EOQ policy to items ". . . which cannot be economically repaired by a field or depot maintenance activity [49:11-3]." Items identified by HQ USAF for EOQ stockage include ". . . consumable items, minor parts, components, tools, and hardware . . . [49:11-3]." Accountability is not maintained on EOQ items once they have been issued. EOQ items are classified under the Expendability, Recoverability, Repairability, Category Designator (ERRCD) XB3 or NF1 (49:11-3). Although the cost of an EOQ item on an individual basis is generally small, it is very significant on an aggregate basis, because of the extremely large number of EOQ items purchased by the USAF (18:1; 52:IV-2).

Both supply efficiency and supply effectiveness are affected by inventory policy. If the sum of ordering and holding costs of inventory is not minimized, the efficiency of the USAF supply system will not be optimal. The ability to accurately determine ordering and holding cost for the base level supply system and the appropriateness of the policy for the USAF have been questioned. If sufficient item quantities are not stocked, the effectiveness of the USAF supply system with regard to operational capability will be reduced (18:2,25).

The USAF uses past experience to forecast future demand for EOQ items. A daily demand rate (DDR) is calculated by dividing the cumulative number of recurring demands by the number of days[1] that have elapsed since the date of first demand (DOFD) (49:11-3). Thus,

$$\text{DDR} = \frac{\text{Cumulative recurring demands}}{\text{Current date--DOFD}}$$

The methodology for computing DDR assumes that an average of past demands can be used to accurately predict future demand. As long as an item has a high turnover rate with little variance in demand, this methodology may be sufficient. For items with low demand rates or high variability the methodology may not provide an accurate forecast of demand (18:53-54). The present method for computing

[1]No fewer than 180 days will be used (49:11-3).

expected demand is intended to dampen the effect of sporadic demand patterns on inventory levels (41). An alternative method for forecasting demand has been proposed. The method uses a Bayesian approach (10). Pending a change in the method for predicting demand, logistics managers must identify essential items that can be expected to experience excessive backorders, because of variability in demand or order and shipping time (O&ST), and establish minimum levels. Minimum levels allow minimum quantities to be stocked that are independent of the EOQ spare asset level or EOQ demand level (EOQ DL) (49:11-49). Until an effective method for forecasting demand is adopted, little else can be done.

The problems that result from using averages to forecast variable values are largely ignored in the base level supply system. As pointed out above, when averages are used to compute variable values, their accuracy is dependent upon the stability of the variable (5:640).

The depth of the EOQ is weighted by variable stockage objective (VSO) days. The VSO reflects the priority of past backorders, the number of past demands, the number of customer orders that generated the demands, the number of days since the first demand was recorded, and the DDR. A VSO table is used to determine the number of VSO days (48:11-37).

USAF inventory policy dictates that the base level supply compute an EOQ spare asset level or EOQ demand level for base stockage when an item has had a minimum of three demands (49:11-4). The EOQ DL is comprised of the EOQ, an O&ST quantity (O&STQ), and a safety level quantity (SLQ). The EOQ portion of the EOQ DL is computed by using the following formula:

$$EOQ = \frac{4.4 \sqrt{DDR \times VSO \times \text{Unit price}}}{\text{Unit price}}$$

where the 4.4 reflects the USAF estimate of a five-dollar cost to order and a 50 percent cost to hold and the unit price is the current USAF stock list price (49:11-13). When a computed EOQ is less than thirty days expected demand (DDR X 30), the EOQ is adjusted to a quantity sufficient for thirty days expected demand. When an EOQ is greater than 365 days expected demand, the EOQ is adjusted to 365 days expected demand (49:11-5).

The O&STQ is the on-hand quantity necessary to support expected demands over the expected order and shipping time. The O&STQ is computed as follows (49:11-13):

$$O\&STQ = DDR \times O\&ST$$

where O&ST is the standard O&ST for the particular base. The standard O&ST is taken from the routing identifier record (49:24-347). A separate routing identifier record

is used for each source of supply. The standard O&ST stored on a routing identifier record is the average O&ST for all receipts of a particular priority group from that source of supply. Unless a minimum of one-hundred receipts has been used in the computation, a predetermined Uniform Material Movement and Issue Priority System (UMMIPS) standard is used. Any receipt with an O&ST greater than 175 percent of the UMMIPS standard for the base's geographic area is excluded from the O&ST calculation. If the calculated base standard O&ST is greater than the UMMIPS standard, the UMMIPS standard is used. O&ST is calculated by source of supply, not by individual item and receipts with excessive O&ST are excluded from the calculation. The standard O&ST on the routing identifier record is updated quarterly (49:11-6A). The current method of computing O&ST is being reevaluated. A proposal has been made to include receipts in the standard O&ST calculation that have an O&ST of up to 200 percent of the UMMIPS standard. Receipts with an O&ST greater than 200 percent of the UMMIPS standard would be included at 200 percent. Additionally, the feasibility of computing O&ST by National Stock Group (NSG) is being studied. A simulation by AFDSDC has produced better results when using NSG rather than source of supply (43:4-5).

If an item had a constant DDR and O&ST, a level could be computed that, if an order for resupply was

established at that level, would ensure no backorder occurrences. The reorder point (ROP), or reorder level, would equal the O&STQ. If DDR was constant at one and O&ST was constant at five days, as long as a reorder was established at a level of five, a backorder would never occur. Unfortunately, neither demand nor resupply time is generally constant. To compensate for variations in demand and O&ST, an SLQ is added to the O&STQ. The sum of O&STQ and SLQ determines the ROP (49:11-8). When DDR, O&ST, or both are not constant, the O&STQ will be sufficient to meet demands approximately 50 percent of the time. An SLQ is required to cover variations above the average. Because both DDR and O&ST are stochastic, it is not possible to compute an SLQ that is certain to meet any possible level of demand. A cost versus benefit comparison must be made to determine the proper performance level to be used as the target (12; 43). USAF policy is to establish an SLQ equal to one standard deviation above the mean. Since approximately 84 percent of the distribution lies below one standard deviation above the mean, the implied target performance level over the resupply interval is approximately 84 percent, i.e., if one-hundred random observations were made during the resupply interval, in approximately eighty-four of the observations no backorders would be expected to exist. Conversely, in approximately sixteen, at least one backorder would be expected to exist

(49:11-6). The SLQ is computed as follows:

$$SLQ = C\sqrt{3(O\&STQ)}$$

where C is the number of standard deviations to be covered by the SLQ, i.e., one (49:11-13). If the SLQ computed using the above formula is less than fifteen days expected demand (DDR X 15), fifteen days expected demand is used for the SLQ (48:11-7). Demand for EOQ items is assumed to be randomly distributed according to a compound, or stuttering, Poisson distribution (18:11). The fact that the mean, O&STQ, is multiplied by three in the SLQ computation indicates that the variance to mean ratio has been assumed to be 3:1.

The computation of an EOQ DL would be performed as follows using the AFM 67-1 methodology. If six requests had been made for a total of seventy-three units in the last year, the DDR would be

$$DDR = \frac{\text{Cumulative recurring demands}}{\text{Current date - DOFD}}$$

$$= \frac{73}{365}$$

$$= .2$$

The VSO would be selected from the referenced table. If the item had experienced no demand of a higher than routine priority, a VSO of sixty days would be used. Thus, the EOQ would be

$$EOQ = \frac{4.4\sqrt{DDR \times VSO \times \text{Unit price}}}{\text{Unit price}}$$

$$= \frac{4.4\sqrt{.2 \times 60 \times 5}}{5}$$

$$\simeq 6.817$$

where the unit price is assumed to be five dollars.

If 146 receipts in this priority group, each with less than 175 percent of the UMMIPS standard, with a combined O&ST of 2190 days, had been received from this source of supply during the previous quarter, a standard O&ST would have been computed as follows:

$$O\&ST = \frac{\text{Total O\&ST days}}{\text{Number of eligible receipts}}$$

$$= \frac{2190}{146}$$

$$= 15 \text{ days}$$

Therefore, the O&STQ would be

$$O\&STQ = DDR \times O\&ST$$

$$= .2 \times 15$$

$$= 3$$

The SLQ would then be

$$SLQ = C\sqrt{3(O\&STQ)}$$

$$= 1\sqrt{3(3)}$$

$$= 3$$

The EOQ DL would be

$$EOQ\ DL = EOQ + O\&STQ + SLQ$$

$$= 6.817 + 3 + 3 + .999^{1}$$

$$\simeq 13$$

The ROP is then equal to six (O&STQ + SLQ).

If O&ST was calculated by item and not by source of supply, as is the current AFM 67-1 procedure, a different O&ST might very well have been computed. For example, if ten receipts for this item, having a total of 300 combined O&ST days, were processed during the last year, including those receipts which were above the 175 percent UMMIPS standard, the standard O&ST would have been

$$O\&ST = \frac{\text{Total O\&ST days}}{\text{Number of receipts}}$$

$$= \frac{300}{10}$$

$$= 30 \text{ days}$$

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[1] The EOQ DL is not rounded but "adjusted" to the next highest unit by adding .999 and truncating (49:11-13).

Then the O&STQ would have been

$$O\&STQ = DDR \times O\&ST$$
$$= .2 \times 30$$
$$= 6$$

And the SLQ would have been

$$SLQ = C\sqrt{3(O\&STQ)}$$
$$= 1\sqrt{3(6)}$$
$$\simeq 4.24$$

Then the EOQ DL would then have been

$$EOQ\ DL = EOQ + O\&STQ + SLQ$$
$$= 6.817 + 6 + 4.24 + 9.99$$
$$\simeq 18$$

More importantly, the ROP would be ten.

In this example the consequence of the AFM 67-1 procedure for computing expected O&ST can be calculated by determining the performance level that an ROP of six, that dictated by the AFM 67-1 procedure, can be expected to provide over the resupply interval. By using a cumulative compound Poisson table with a variance to mean ratio of 3:1, it can be demonstrated that an ROP of six will provide an expected performance of .6130, when the true

mean, O&STQ, is six. So, approximately sixty-one times in one-hundred random observations across the resupply interval, no backorders would be expected to occur. Conversely, in thirty-nine instances at least one back-order would be expected to occur. However, an ROP of ten, that dictated by an item approach without time constraints, provides an expected performance level of .8576. This should raise the number of instances that no backorders are observed in one-hundred random observations across the resupply interval to approximately eighty-six. Conversely, an ROP of ten would lower the number of instances at least one backorder was observed to approximately fourteen, a decrease of twenty-five. Thus, the ROP of ten, that which was computed on an item basis, provides the performance level implied by USAF policy (28:44).

A capability exists for base level managers to compute O&ST on an item basis to determine whether or not the standard O&ST used in the level computation is accurate. Pipeline time cards can be produced in the SBSS at the option of base level managers (49:7-14). When the pipeline time cards provide a significantly different average O&ST for an item, there is a methodology for using an exception O&ST instead of the standard. The use of an exception O&ST is restricted to those items for which the source of supply has indicated an extended procurement time and that are not normally stocked by the source of supply.

Exception O&ST ". . . will not be used to compensate for temporary out of stock conditions which may be experienced by the source of supply from time to time [49:11-7]." While the restriction on the use of exception O&ST does not allow its use in every case where the standard O&ST is significantly different from the computed O&ST, it does provide a measure of relief.

Not all items from a single source of supply can be represented equally well by a single standard O&ST. The varying difficulties associated with maintaining an on-hand stock of various items at the source of supply should be reflected in a distribution of average order-filling times. Also, the average shipping time should be shown to vary according to mode of shipment. Different sized items may require different modes of shipment and different handling techniques (43:29-30).

Expected time-weighted backorders can also be computed for the AFM 67-1 policy and the unconstrained policy (29:14; 22). When using time-weighted backorders, the effect of a backorder for one unit which lasts for ten days is considered to be equal to the effect of ten backorders for one unit, each lasting a single day. When using the AFM 67-1 methodology, 1.2732 time-weighted backorders per order cycle would be expected rather than the .3934 expected using the unconstrained policy. Over

three times as many time-weighted backorders would be expected to occur in this example, when the current AFM 67-1 methodology is used.

A further complication in the AFM 67-1 routine is sometimes introduced. EOQ items stocked at the base supply must be purchased by the Air Force Stock Fund. When a customer purchases an item, the stock fund is reimbursed from Operations and Maintenance funds. If base stock fund purchases exceed sales, restrictions have to be placed on stock fund purchases. One method of reducing stock fund expenditures is to restrict purchases to a percentage of the computed EOQ portion of the EOQ DL. A Material Acquisition Control Record (MACR) factor is used for this purpose (49:26-23). As an example, when a 50 percent MACR factor is used, 50 percent of the EOQ is ordered instead of the full EOQ. The effect of this policy is to double the number of expected orders. In the AFM 67-1 example being used, the computed EOQ was 6.817 and the DDR was .2. A DDR of .2 equates to an annual demand, D, of seventy-three units. The expected number of annual orders, N, is computed using the following formula (27:120):

$$N = \frac{D}{EOQ}$$

$$= \frac{73}{6.817}$$

$$\simeq 10.7$$

When a 50 percent MACR factor is used, the number of expected orders is twice as many or 21.4. Since the expected time-weighted backorders per order interval is the same, the expected time-weighted backorders per year are doubled when only 50 percent of the EOQ is ordered. Base level supply system efficiency is also adversely affected, since the sum of ordering and holding costs is no longer minimized. The increased number of orders also increases the workload throughout the system.

Another point concerning the AFM 67-1 computation needs to be made. The procedure assumes that orders are placed to the source of supply when the ROP is reached. In fact, only a notation on the item record is made when the ROP is reached. Periodically all item records are screened and reorder action is taken on records having reorder notations (49:11-8). If the screening is not done and a reorder is not placed on the same day as the ROP is reached, the computed O&ST will not reflect the delay. Likewise, if reordering is routinely delayed for funding approval, the delay will not be computed in O&ST. All delays in reordering can be expected to result in a greater probability of incurring at least one backorder during the reorder interval and, therefore, more time-weighted backorders (49:6-5,26-24).

The Recoverable Item Model

Base spare asset levels for items that can be economically repaired and reused, recoverable items or repair cycle items, are computed using a formula contained in AFM 67-1 (49:11-13). The formula is assumed to compute levels which will ensure that, if a large number of random observations of an item are made, 84 percent of the time no backorders will be observed. The computation is based on predicting the DDR for an item and the expected time for resupply. DDR is computed in the same manner as in the EOQ formula. Resupply time is determined by the replenishment source. If an item is always repaired at the base level, the model uses the average base repair cycle time, excluding any time the item awaits repair parts, up to six days for ERRCD XD1/XD3 items and nine days for all others (49:11-7). If replenishment always comes from an off-base source of supply and the item is not an airlift investment item, the procedure is the same as for computing O&ST for EOQ items. AFLC provides the time to be used for each AFLC source of supply for airlift investment items (49:11-6A). If an item is sometimes repaired at the base level and sometimes resupplied from an off-base source of supply, a weighted average of base repair cycle time (RCT) and O&ST is used.

A pipeline quantity is computed to support expected demands over the resupply interval. The pipeline quantity

is comprised of quantities necessary to cover average expected demands during the base repair cycle, average O&ST from an off-base source of supply, and average delays in requisitioning due to Not Reparable This Station (NRTS) and Beyond Economical Repair and Will Be Condemned (COND) verification.

By determining the percentage of the time that a given item is repaired at the base level, percent of base repair (PBR),[1] the quantity required to support average demand during the expected base repair cycle, repair cycle quantity (RCQ), can be computed. It is computed as follows (49:11-3):

$$RCQ = DDR \times PBR \times RCT$$

The O&STQ is computed as follows: (49:11-3):

$$O\&STQ = DDR \times (1-PBR) \times O\&ST$$

The final quantity required to complete the determination of stock required to support average resupply time is a quantity used during a period of unsuccessful repair efforts or during the time of determining that an item cannot be repaired at the base level. This quantity is known as the NRTS/COND quantity (NCQ). A requisition will not be submitted to the source of supply for a replacement

[1]Actually, the decimal equivalent is used in each case that the PBR is listed in the model.

until a repair cycle item is turned in as NRTS or COND (49:11-8). NRTS/COND time (NCT) is always set at two days. NCQ is computed as follows (49:11-3):

$$NCQ = DDR \times (1-PBR) \times NCT$$

The sum of RCQ, O&STQ, and NCQ will support demands over the resupply interval approximately 50 percent of the time. To raise the expected performance level to the target level, an SLQ must be added. the SLQ is computed as follows (49:11-3):

$$SLQ = \sqrt{3(RCQ + O\&STQ + NCQ)}$$

The base level supply system repair cycle inventory model is as follows (49:11-13):

$$RCDL = RCQ + O\&STQ + NCQ + SLQ$$

where RCDL is the repair cycle demand level or recoverable spare asset level. The ROP is one less than the RCDL (49:11-8). A minimum of two recurring demands is required before an RCDL will be established (49:11-4).

A spare asset level for a recoverable item is computed as follows. Values for the four variables DDR, PBR, RCT, and O&ST are determined. DDR is computed in the same manner as for the EOQ model. Cumulative recurring demands are divided by the number of days since the first

demand was recorded. A minimum of 180 days is used and, normally, the maximum retained history in the base supply computer will be five quarters or 450 days (49:11-3). In this example cumulative recurring demands will be assumed to be 252 and 416 days will be used as the time since the first demand.

$$\text{DDR} = \frac{252}{416}$$

$$= .6057^{1}$$

The PBR would be calculated by dividing the total number of units of the item repaired at the base level during the past five quarters by the total number of units repaired, processed as NRTS, or condemned. If eighty-eight units were repaired, ten were processed as NRTS, and two were condemned, PBR would be calculated as follows (49:11-3):

$$\text{PBR} = \frac{\text{Units repaired}}{(\text{Units repaired} + \text{NRTS} + \text{COND})}$$

$$= \frac{88}{(88 + 10 + 2)}$$

$$= .88$$

RCT is computed by dividing the total number of days it has taken to repair all units of this item during the past

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[1]All figures illustrating the current base supply computation will be truncated to the number of decimal places the computer uses. The current procedure is to truncate rather than round.

five quarters, less any time awaiting parts (AWP), by the total units repaired. RCT is limited to six days for ERRCD XD1/XD2 items and nine days for all others. This example assumes that the item is ERRCD XD3. If 2243 days were used to repair 223 items RCT would be computed as follows (49:11-7):

$$RCT = \frac{\text{Net repair cycle days}}{\text{Number of units repaired}}$$

$$= \frac{2243}{223}$$

$$\simeq 10$$

Ten days exceeds the six-day maximum RCT, therefore, six days are used for RCT. O&ST is determined by selecting the time stored on the routing identifier record for the particular source of supply (49:11-6A). Fifteen days will be assumed in this example. A constant of two days is used for NCT under the current AFM 67-1 methodology.

Thus, the demand level would be computed as follows:

$$RCQ = DDR \times PBR \times RCT$$

$$= .6057 \times .88 \times 6$$

$$= 3.1980$$

$$O\&STQ = DDR \times (1-PBR) \times O\&ST$$

$$= .6057 \times (1-.88) \times 15$$

$$= 1.0902$$

$$NCQ = DDR \times (1-PBR) \times NCT$$

$$= .6057 \times (1-.88) \times 2$$

$$= .1453$$

$$SLQ = \sqrt{3(RCQ + O\&STQ + NCQ)}$$

$$= \sqrt{3(3.198 + 1.090 + .145)}$$

$$= 3.6467$$

$$RCDL = RCQ + O\&STQ + NCQ + SLQ$$

$$= 3.1980 + 1.0902 + .1453 + 3.6467 + .5^{1}$$

$$\simeq 8$$

While this computation is assumed to provide approximately an .84 probability of not observing a backorder, when a large number of random observations are made, the constraints placed on RCT, O&ST, and NCT reduce the performance level. In this example, RCT was limited to six days although computed RCT was ten days and AWP time was

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[1] The .5 is added to the computation and the result is truncated in the base level supply system when the unit price is greater than $751. If the unit price is less than $751 a .9 factor is added (49:11-4). This example assumes a unit cost greater than $751.

not included. The effect of these constraints distorts the computation of the mean, λ, of the distribution. Demands for recoverable items can be modeled reasonably well by a compound or stuttering Poisson distribution (11:5). The computation of the SLQ demonstrates that the variance to mean ratio is assumed to be 3:1, since the mean, λ, or the sum of RCQ, O&STQ, and NCQ is multiplied by three. The mean in this example is assumed to be four using the AFM 67-1 calculations. If the constraints on the variables and NCT are relaxed, the effect of this policy can be calculated. Actual RCT for this item, including AWP time might be twelve days (RCT less AWP time has been shown to be ten days, so two days average AWP time is now included). The actual O&ST for this particular item is assumed to be sixteen days. NCT is assumed to be six days, including AWP time. The proper demand level providing a .84 probability of no backorders would be computed as follows:[1]

$$RCQ = DDR \times PBR \times RCT$$
$$= .6057 \times .88 \times 12$$
$$= 6.3962$$

[1]All figures will be rounded and not truncated.

$$O\&STQ = DDR \times (1-PBR) \times O\&ST$$

$$= .6057 \times .12 \times 16$$

$$= 1.1629$$

$$NCQ = DDR \times (1-PBR) \times NCT$$

$$= .6057 \times .12 \times 6$$

$$= .4361$$

$$SLQ = \sqrt{3(RCQ + O\&STQ + NCQ)}$$

$$= \sqrt{3(6.3962 + 1.4537 + .4361)}$$

$$= 4.8975$$

$$RCDL = RCQ + O\&STQ + NCQ + SLQ$$

$$= 6.3962 + 1.1629 + .4361 + 4.8975$$

$$= 12.8927 \text{ or } 13^{1}$$

A cumulative compound Poisson table (28:44) can be used to reveal the difference in the expected performance level. Since the true mean of the distribution is approximately eight, not 4.4335, as in the present AFM 67-1 computation, the level of eight, computed above, will only provide approximately a .60 probability of not observing

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[1] The computed level must be rounded to the next highest whole unit to insure a level of support at least as large as implied by the formula.

a backorder. This contrasts with the approximately .87 probability that occurs when the constraints are relaxed. Thus, a decrease of .27 in expected performance results in this example, using current USAF methodology.

While constraints placed on RCT, O&ST, and NCT encourage effective use of resources, the effect of any variable's value that exceeds the constraints is not often calculated or known.

Expected time-weighted backorders could also be computed for recoverable items. Using the current AFM 67-1 procedure, approximately 1.5 time-weighted backorders would be expected, while .4076 would be expected using the unconstrained procedure.

The computation of the RCDL example, with and without the AFM 67-1 constraints on RCT, O&ST, and NCT, illustrates the divergence in expected performance that the constraints can cause. The effect of limiting RCT to a fixed number of days is recognized by AFM 67-1. A provision has been made in AFM 67-1 for loading an exception RCT, or as termed in AFM 67-1, "exception repair cycle days," on the repair cycle record. The exception repair cycle days would then be used in lieu of RCT in the RCDL computation. The Stock Control Section of base supply is responsible for identifying all recoverable items that have an RCT greater than the standard (49:11-7). A SBSS report entitled the "Repair Cycle Data List" (Q04)

identifies all items having RCTs greater than the standard (49:24-342). The Stock Control Section is supposed to compare the current quarter RCT to the total average RCT.

> This comparison will reveal if significant increases in repair cycle time is [sic] occurring and may indicate that additional products, such as inquiries, may be required to determine the true impact of above average repair cycle days upon support effectiveness [49:11-7].

No methodology for calculating the impact of an RCT greater than the standard is provided in AFM 67-1. Thus, the Stock Control Section must develop its own methodology for determining when to recommend the use of exception repair cycle days. Also, the constraint of excluding AWP time from RCT is carried forward in the calculation of exception repair cycle days. Average AWP time cannot be included in the calculation of exception repair cycle days (49:11-7).

While RCT is computed by item, O&ST is not. As explained in the description of the recoverable item model, O&ST is either computed by source of supply or, for AFLC-managed airlift investment items, provided by AFLC to the base for each source of supply. The methodology for computing exception O&ST is the same as for the EOQ model.

A standard NCT of two days cannot be expected to be accurate for all items. Some recoverable items are not authorized any repair at the base level while others are authorized at least a partial degree of base level repair. An item that is authorized at least some level

of repair has to be checked to determine whether or not the appropriate repair action is authorized at the base level. The time to process an automatic NRTS differs from the time required to bench check and then complete NRTS action.

A conceptual inconsistency exists in computing expected resupply time. RCT is calculated by item, O&ST is calculated by source of supply, and NCT is treated as an identical, constant, deterministic time for all recoverable items. If an item is always repaired at the base level, the resupply time is calculated using data based only on the base repair history for that item. If an item is never repaired at the base level the resupply time may be calculated based upon data for all items from the common source of supply or the resupply time may be directed by AFLC. In addition for those items never repaired at the base level, the time to NRTS is considered to be the same for all recoverable items. Finally, for those items that are repaired at the base level at least some of the time, but not all of the time, a weighted average of all the methods is used.

In its 1972 meeting, the Chapter 11/17 Work Group addressed the use of fixed time standards in the recoverable item and EOQ item models. At that time a fixed number of days was used in the inventory models for RCT and O&ST. The time used for O&ST was also supposed to

cover NCT. At that meeting the group recommended that actual times be computed and used in the inventory computations for base repair cycle time, including AWP and NCT. The group also recommended that the present AFM 67-1 method for computing O&ST be adopted (39). HQ USAF has since dropped the use of fixed times for RCT and O&ST and adopted a fixed time for NCT. While AFM 67-1, Volume II, Part One, states,

> When the capability to measure and record actual base NRTS and condemned time is developed, a separate quantity of stock will be computed for this processing cycle. At that time the two day NRTS and condemned time will no longer be added to the O&ST [49:11-5],

AFDSDC currently has not received any instructions for making the necessary programming changes (26). HQ USAF did not approve the inclusion of AWP time in the RCT calculation. AFLC recommended that AWP time not be included, because to do so would raise the levels of the recoverable items and do nothing to resolve the EOQ shortages that create the AWP time (39).

Finally, as stated in the EOQ model, any delay in reordering after the ROP is reached is not reflected in O&ST. These delays in reordering may result in a larger number of time-weighted backorders.

The Engine Model

USAF spare engine levels are computed using a formula contained in AFM 400-1 (45:8-5). The formula has

an implied performance level--either a 70 or 80 percent probability, depending upon the unit precedence, that no backorder will exist during any random observation.

The variables of the base level spare engine computation are demand rate and resupply time. The demand rate is assumed to be a function of engine operating time (27:1). Spare engines are demanded to replace engines that require maintenance or that have reached a maximum operating time or maximum number of repair cycles (13:9). The resupply of spare engines can come from either base maintenance or an off-base source of supply. The expected resupply time is a function of the source of resupply. To achieve a given expected performance level, a safety level factor is added to the average pipeline quantity.

AFLC actuaries forecast engine demands by TMS. Removal intervals for both depot overhaul and base maintenance are calculated and published in the Actuarial Removal Table (45:8-1). By dividing the expected flying hours by the overhaul removal interval (OHRI), the expected requirements for depot resupply can be determined. Likewise, by dividing expected flying hours by the base maintenance removal interval (BMRI), the expected requirements for base maintenance resupply can be computed. Expected flying hours are determined by selecting the larger of one-third of the highest quarterly peacetime projected flying hours or the thirty-day war program. Projected peacetime flying

hours can be found in the appropriate volume of Aerospace Vehicles and Flying Hours PA, while the thirty-day war program can be found in Volume Six of the USAF War Mobilization Plan (45:4-1).

AFLC and the Engine Logistics Planning Board have established standards for resupply time that are used in the computation of spare asset levels. Automatic Resupply and Buildup Time (ARBUT) represents the time required to receive a replacement engine from the depot and build it up to a ready-to-use condition. Base maintenance time is the period required to repair engines at the base level (45:7-3).

ARBUT consists of four subsegments:

Base Notice to Shipment

Transportation CONUS/OS

Receive Trans Start Work

Buildup (In Work) (45:7-5)

Base Notice to Shipment consists of the interval from the time the base engine manager notifies AFLC that a replacement is required until the time the spare is delivered to transportation at the depot. The second segment of ARBUT is titled Transportation CONUS/OS and represents the time it takes transportation to deliver the spare to the base. The third segment is titled Receive Trans Start Work and represents the period from receipt by the base transportation office until the engine is placed in work at the

engine shop. The final segment of ARBUT is titled Buildup (In Work) and represents the period used to buildup the raw engine by adding a Quick Engine Change Kit (45:7-5).

Base maintenance time or "Base Maintenance Cycle" consists of two segments. The first is "Removal to Start," which represents the interval from the time of removal of an engine until the engine is placed in work in the engine shop. The second segment is "In Work" which represents the period required to complete maintenance on the engine (45:7-5).

The safety level factor reflects the unit's precedence priority rating as listed in <u>USAF Program, Bases, Units and Priorities (PD)</u> (45:4-1). The safety level factor supposedly provides either a .70 or .80 probability that no backorder will exist at any given time. If only the average pipeline quantity, computed using average demand and resupply time were used for spares, the level would be sufficient approximately 50 percent of the time. To cover variation above the average, a safety level factor is added. The safety level factor is the number of engines necessary to raise the computed average pipeline level nearest the target performance level.

The spare engine level for a base possessing five single engine aircraft of a single TMS would be computed as follows. The OHRI and BMRI would be found in the Actuarial Removal Table. For this example, OHRI and BMRI

will be assumed to be 1391 and 622 hours, respectively. Expected flying hours will be assumed to be a total of 1000 hours, or 200 hours per aircraft and engine. The ARBUT and base maintenance time standards for the engine TMS would then be found in AFM 400-1. An ARBUT standard of fifteen days and a base maintenance standard of twenty-six days will be used.

By dividing the peak thirty-day expected flying hours (1000) by the OHRI (1391 hours), an average of .719 removals per month or .024 per day for depot overhaul results. Likewise, by dividing the peak thirty-day expected flying hours (1000) by the BMRI (622 hours), an average of 1.608 removals per month or .054 per day for base maintenance results.

Since the ARBUT standard is fifteen days, a spare stock necessary to support demands over the fifteen-day depot resupply time will be necessary. By multiplying expected removals per day (.024) times the ARBUT time (fifteen days), a level (.36 engines) necessary to provide support for average demand during average depot resupply is computed. Similarly, since the base maintenance standard is twenty-six days, a stock necessary to support demands over the twenty-six day base maintenance resupply time will be necessary. By multiplying expected removals per day (.054) times the base maintenance time (twenty-six days), a level (1.393 engines) necessary to provide support

for coverage demand during average base resupply is computed. By adding the ARBUT level (.36 engines) and the base repair cycle level (1.393 engines), a level to support total average demand (1.753 engines) is computed. As stated above, this level will support demands approximately 50 percent of the time. If this unit was authorized an 80 percent safety factor, an additional .247 engines would be required to support variation between the mean and the safety factor. The safety level was calculated by determining what level would be required to provide the closest number of whole engines to the desired target performance level. Thus, the spare engine level would be two. Since demands for engines have been shown to be randomly distributed according to a Poisson distribution, a cumulative Poisson probability distribution table could be used for this purpose (13:10). The mean, λ, was calculated above to be 1.753. The Base Safety Level Table found in AFM 400-1 is normally used to compute the number of spare engines authorized (45:8-8). The ROP is one less than the computed level.

The spare engine level formula contains the same limitations as are found in the recoverable item formula. Because ARBUT and base repair cycle time are constants the computed level does not always provide the implied performance level. Additionally, because the engine nearest the implied performance level is selected (even

assuming that the computed mean is correct), the level does not always provide the level of protection implied. For example, if the ARBUT and base repair cycle times listed above should actually be twenty days and thirty-five days, respectively, the mean of the distribution would be

$$\lambda = .024 \times 20 + .054 \times 35$$
$$= 2.37$$

A level of two engines would only provide a .5776 probability of not observing a backorder. If the correct mean of 2.37 was used to compute the proper level from the Base Safety Level Table, a level of three would be authorized. Three spares would only provide a .7850 probability of not observing a backorder. To raise the performance level to the implied level of .80, a level of four engines would be required. While, in this case, three engines provide a performance level close to the implied performance level, the table does not always come so close. For example, with a mean of 1.850 the table calls for a level of two engines. Two engines provide a .7172 probability of not observing a backorder at any given time (14:8-8).

Using the level of two as was computed with the AFM 400-1 resupply times, 1.9031 time-weighted backorders per year would be expected if flying hours were distributed

evenly. With the level of four, computed using the actual resupply times, .5868 time-weighted backorders per year would be expected.

CHAPTER IV

USAF BASE LEVEL SUPPLY SYSTEM MANAGEMENT INDICATORS

All three base level inventory models implement USAF inventory policy. The models reveal the performance level desired by HQ USAF. The implied performance level for the EOQ model is a .84 probability of not observing a backorder during the reorder interval. The implied performance level for the recoverable item model is a .84 probability of not observing a backorder during any random observation. Finally, the implied performance level for the engine model is either a .70 or .80 probability of not observing a backorder during any random observation.

Evaluation of base level supply system effectiveness in terms other than those based on the individual item's performance level may be useful in analyzing the effectiveness of USAF inventory policy, but it is not appropriate for determining the effectiveness with which the policy is carried out. As stated earlier, base level logisticians must work towards the accomplishment of the present policy. To do so they must have meaningful information with which to evaluate their performance and a methodology for controlling item variables. Beer has said

". . . if a system has a criterion of smooth operation, it can be organized to work towards that criterion [2:37]."

Chapter III explained the inventory models and demonstrated the effect variable values can have on an item's performance. When the actual value of the variable differs from the value used in the computation the effect on the item's performance can be calculated. The change in the expected number of backorders for the item can also be calculated. RAND has demonstrated that, by minimizing backorders, the NORS rate is "approximately" minimized (30:24). While today's NORS rate is not useful in making decisions about the allocation of resources, it does describe one result of the lack of serviceable components. Minimizing backorders should also reduce NORM created while items are repaired.

In essence, the base level logistician must know which factors affect the number of expected backorders and he must act to maintain these factors within acceptable limits.

Present Major Indicators

In Chapter I, the NORS rate, the primary measure used to evaluate the supply system, was examined. The NORS rate is also the primary measure used to evaluate the base level supply system. Base level managers use "cause codes" to attempt to determine the cause of NORS

occurrences (49:6-88,24-294; 56:24). The cause code identifies the base supply inventory position at the time of the NORS request, i.e., whether or not the item was stocked; if stock was available but could not be used; or if stock was not available, whether it was on order and, if so, whether the requisition exceeded UMMIPS O&ST standards (49:6-88). As was pointed out in Chapter I, a NORS condition's cause can be more complicated than can be detected by examining the base supply inventory position. As has been emphasized, the NORS rate does not provide a useful method for evaluation or control of inventory decision making.

The issue effectiveness rate, a secondary measure used to evaluate the supply system, was also examined in Chapter I. While issue effectiveness considers the ratio of line items issued to line items requested, stockage effectiveness only considers requests for items authorized to be stocked at a particular base at the time of the request. So, the stockage effectiveness rate is the ratio of line items that were authorized base stockage and issued to the line items that were authorized base stockage and requested during a given period. Stockage effectiveness rates and issue effectiveness rates suffer from the same drawbacks (8:5; 49:24-284). Issue effectiveness and stockage effectiveness rates, as well as other SBSS indicators yet to be discussed, are found in the "Monthly Base

Supply Management Report" (M32) and the "Daily Base Supply Management Report" (D14). The daily report is used to update the monthly report. Since it is difficult to detect trends by looking at a daily report, the monthly report is more often used for trend analysis. Data on the monthly report are reported to higher headquarters (34; 35; 36; 38). The "Monthly Base Supply Management Report" has been described as follows:

> This is the single most important report in the base supply account and most managers feel that the product they send to the command at the end of the month should look as good as possible. . . . This report is intended to be used at all levels of Air Force command. Base level supply is the prime user of the report and they should use it to insure the account is in a satisfactory condition. The major commands use the report as one of the tools for the measurement of the base against the established command standards or goals. . . . This report is also used by Headquarters USAF in data analysis programs conducted by the Air Force Data Systems Design Center (AFDSDC). . . . This enables the Design Center to extract data to produce the Selected Items Review [33:1].

Present Minor Indicators

The effect of variable values on the inventory models has not been completely overlooked. The "Monthly Base Supply Management Report" provides various summary statistics for supply system managers. In addition, various other reports provide a more comprehensive analysis of many of the areas covered on the "Monthly Base Supply

Management Report," e.g., the "Repair Cycle Data List" and the "Routing Identifier Listing [49:24-341,347]."

Minimizing the expected number of backorders approximately minimizes the NORS rate. Backorders are minimized by maintaining inventory variable values within the established standards. Thus, the effectiveness of present base supply system indicators in controlling inventory variable values is of the utmost importance.

The EOQ Item Model

Relevant factors with regard to the EOQ item model include its variables' values, whether or not the MACR factor or any other method of reducing or delaying inventory purchases is being employed, and what the expected reordering delay is, once the ROP is reached.

The EOQ item model variables are DDR and O&ST. As was previously discussed, DDR is a good forecast of future demand only if a given item has a high turnover rate and little demand variance. Unfortunately, there is currently no indicator with which to monitor DDR effectiveness.

O&ST summary statistics are found both on the "Routing Identifier List" and on the "Monthly Base Supply Management Report" (49:24-320D,347). The statistics provide no identification of items with variable values greater than the standard employed in the level computation. Since individual items are not identified, there is no capability

for true control. For example, both listings provide the number of receipts that exceed the UMMIPS O&ST standard. However, this statistic does not indicate whether or not the expected O&ST for the items concerned is beyond the UMMIPS standard. Further, the statistic does not identify items with expected O&STs that will lower item performance below USAF standards (43:5). Finally, statistics are not available to indicate the percentage of items with O&STs greater than the UMMIPS standard.

Financial restrictions on inventory purchasing can be found by reviewing the MACR (49:23-74,26-22). The expected reduction in purchasing can be calculated using SBSS programs, but not the effect on system performance (49:26-23).

The "Monthly Base Supply Management Report" also indicates the number of times that the file was completely scanned for reordering or releveling (49:24-267). This statistic does not necessarily provide a valid means of evaluation or control. The time required to relevel can be expected to increase as the time since the last releveling increases. If relevelings happen to be clustered, the indicator will not reflect it. Releveling will appear to have been accomplished evenly throughout the month. For example, releveling might not be accomplished at all during the first two weeks of the month, but then accomplished daily for the remainder of the month. If

the number of relevelings is then used to evaluate performance, it would be assumed that releveling was accomplished every other day. The expected result of such a clustered releveling pattern would be decreased inventory performance because of the lengthy delay in initial releveling.

The Recoverable Item Model

The recoverable item model factors include the variables and the expected delay in releveling. The current releveling indicator was previously examined.

The variables of the recoverable item model are DDR, O&ST, PBR, RCT, and NCT. Daily demand rate and O&ST were previously examined. Summary statistics for PBR are provided in the "Repair Cycle Data List" and the "Monthly Base Supply Management Report" (49:24-285,341). The "Repair Cycle Data List" only provides the PBR for each item and does not monitor changes in PBR for statistical significance. The number of times items were processed as NRTS due to the lack of a base resource is provided. The manual screening of each item's data is the best method presently available to detect problems with the PBR (49:24-341). The "Monthly Base Supply Management Report" provides a summary statistic for the percent of items repaired, but the statistic does not provide any information as to individual item performance.

RCT statistics are also found in the "Repair Cycle Data List" and the "Monthly Base Supply Management Report" (49:24-215,341). As was stated previously, RCT is computed for each recoverable item, but AWP time is excluded from the calculation. Also, a maximum RCT standard has been established by ERRCD for recoverable items model usage. "Repair Cycle Data List" does provide a list of items that have an RCT which exceeds the USAF standard. Thus, base level managers do have the capability of identifying recoverable items that have an "excessive" RCT (49:24-341). The list of items which exceed the standard can be used to identify items which cannot be repaired within the RCT standard and, therefore, qualify for the use of exception repair cycle days (49:11-7). Items which do not qualify for exception repair cycle days must then be brought within standards. Unfortunately, the list does not identify items with an RCT which is so excessive that it reduces expected performance wither below that which would be expected if the standard RCT was achieved or below the implied performance level, whichever is lower. An item may have an RCT which exceeds the USAF standard, but the item's performance may not fall below the lower of implied performance or that performance which could be expected using the standard RCT. For example, assume that an XD2 item with a unit price of $1000 has a .0274 DDR, a sixteen-day standard

O&ST, and a thirteen-day RCT. The AFM 67-1 level would be computed as follows:

$$RCQ = DDR \times PBR \times RCT$$

$$= .0274 \times 1.0 \times 9$$

$$= .2466$$

$$O\&STQ = DDR \times (1-PBR) \times O\&ST$$

$$= .0274 \times (1-1.0) \times 16$$

$$= 0$$

$$NCQ = DDR \times (1-PBR) \times NCT$$

$$= .0274 \times (1-1.0) \times 2$$

$$= 0$$

$$SLQ = \sqrt{3(RCQ + O\&STQ + NCQ)}$$

$$= \sqrt{3(.246 + 0 + 0)}$$

$$\simeq .8601$$

$$RCDL = RCQ + O\&STQ + NCQ + SLQ$$

$$= .2466 + 0 +) + .8601 + .5$$

$$\simeq 1$$

A level of one provides approximately a .9377 probability of not observing a backorder. The probability

is greater than the implied level, because one is the minimum positive quantity that can be stocked. A comparison with the computation using the thirteen-day RCT shows that no greater level is calculated and, although the mean is higher, the expected performance is still approximately .90, which is greater than the implied performance level.

$$\begin{aligned}
RCQ &= DDR \times PBR \times RCT \\
&= .0274 \times 1.0 \times 13 \\
&= .3562
\end{aligned}$$

$$\begin{aligned}
O\&STQ &= DDR \times (1-PBR) \times O\&ST \\
&= .0274 \times (1-1.0) \times 16 \\
&= 0
\end{aligned}$$

$$\begin{aligned}
NCQ &= DDR \times (1-PBR) \times NCT \\
&= .0274 \times (1-1.0) \times 2 \\
&= 0
\end{aligned}$$

$$\begin{aligned}
SLQ &= \sqrt{3(RCQ + O\&STQ + NCQ)} \\
&= \sqrt{3(.356 + 0 + 0)} \\
&\cong 1.0334
\end{aligned}$$

$$\begin{aligned}
RCDL &= RCQ + O\&STQ + NCQ + SLQ \\
&= .3562 + 0 + 0 + 1.0334 + 5 \\
&\cong 1
\end{aligned}$$

The point is, that although an RCT is not within USAF standards, there should be a method for determining which items require the greatest effort or expense to bring within standards.

No AWP data are retained on the repair cycle record, so they cannot be used on the "Repair Cycle Data List" to detect the effect of AWP time on item performance. RCT data provided on the "Monthly Base Supply Management Report" are of the same nature as the O&ST data. Only summary statistics are provided and the significance of the statistics cannot be determined (49:24-285). Only summary statistics for NCT are available on the "Monthly Base Supply Management Report." As with the RCT and O&ST statistics, the NCT statistics are of little use, because they do not identify problem items (49:24-285).

<u>The Engine Model</u>

The engine model factors are its variables. Currently, no information concerning the engine model's variable values is supplied to base level managers from the Propulsion Unit Logistics System. The information is not officially provided below the command engine manager level (6; 19; 25; 45:6-1). Certainly base managers should have some direct feedback on expected engine model performance.

CHAPTER V

RECOMMENDATIONS AND CONCLUSIONS

Effective indicators are needed to evaluate and control the base level supply system. The present SBSS indicators do not provide the most effective means of insuring that base level supply system performance meets the implied performance levels. In addition, indicators need to be used at the base level to control and evaluate spare engine level performance.

As indicated previously, base level managers must carry out USAF policy. The indicators that will be recommended will not be designed to change current policies but only to reflect the effect of current policies. Recommended indicators for each model will be provided. These indicators are intended to be "real world" indicators. Their adoption will require the modification of some current computer programs. The 1974 Chapter 11/17 Work Group made the following observation:

> The available studies on the topic of EOQ fall into two classes:
>
> a. First are those which are generated by sources outside of the AF supply environment. These tend to be based on substantial expertise in mathematical techniques, but fail to offer practical alternatives for lack of understanding of "real-world" AF mission requirements.
>
> b. The second class of studies are generated from internal AF logistics sources. These tend to have

> two failings. First, while critical of current EOQ methodology, they do not provide alternative approaches. Secondly, they are not based on the needed mathematical expertise, especially in inventory management modeling techniques [40:19].

While this thesis deals with base level supply system indicators the preceding message is relevant to this work. The "real world" has not been forgotten and neither has the USAF mission. The indicators recommended will enable managers to work more effectively toward accomplishing USAF policy.

Recommended EOQ Item Model Indicators

O&ST

Current programming should be changed to capture O&ST data for each item. The present policy, i.e., that the bast standard for O&ST cannot exceed the UMMIPS standard, would still be followed. By capturing data on each item, a comparison could be made between the actual O&ST and the UMMIPS standard. While the UMMIPS standard would be used as the maximum O&ST in the level computation, there would be a method for identifying items with actual O&STs that exceed the standard. Programs should also be written to compute what the ROP would be if actual O&ST exceeded the UMMIPS standard. A comparison of the actual ROP with the unconstrained ROP would reveal the effect on performance. If the comparison revealed an expected performance level either below that which could be expected

if the UMMIPS standard was achieved or below the implied performance level, whichever is lower, the item would be "flagged" as having an excessive O&ST. Base managers could then query the source of supply to determine whether or not the item qualifies for exception O&ST days. If so, the exception days would be used. If the item does not qualify for exception O&ST days, the source of supply will have at least been alerted to the poor support.

The Current "Routing Identifier Listing" should be used to identify items with an actual O&ST which is excessive. This is currently done with RCT on the "Repair Cycle Data List." In addition, the listing should be used to identify sources of supply that are providing poor support. Summary statistics should be computed to provide the percentage of items from each source of supply that have actual O&STs that exceed UMMIPS standards. HQ USAF performance targets should be used in evaluating each source of supply. A separate number and percentage of items with sufficient exception O&ST should be calculated.

The management indicator should be provided on the "Monthly Base Supply Management Report." This indicator should be a restatement of the summary statistics from the "Routing Identifier Listing," i.e., the overall statistic on the percentage of stocked items with current actual O&STs greater than UMMIPS standards, and a summary by

category of sources of supply, e.g., AFLC, DLA, GSA, etc. Separate statistics should be computed for items with sufficient O&ST.

Financial Restrictions

The "Monthly Base Supply Management Report" should indicate the MACR factor stratification displayed on the Financial Management Summary (49:24-320E). In addition, the expected increase in the number of orders placed should be calculated and provided to indicate the increase in system workload and to highlight the inefficiencies thus created. Additionally, if requisitioning is being delayed for funding approval, an entry should be made on the report to display the criteria.

Releveling

HQ USAF should establish a standard for time between computing requirements and releveling and the "Monthly Base Supply Management Report" should reflect the number of times the standard was exceeded.

Recommended Recoverable Item Model Indicators

RCT

The "Repair Cycle Data List" should be changed to include items that have an RCT excessive enough to reduce expected performance below that which could be expected if the standard RCT was achieved or below the implied

performance level, whichever is lower. Base managers would then be able to determine which items qualify for exception repair cycle days. The remaining items with excessive RCTs could then be reviewed by the base level managers in order to determine the required corrective action.

While average AWP time should not be included in the level computation, it should be used in determining excessive RCT. AWP data should be captured on the repair cycle record and provided on the "Repair Cycle Data List." When an item appears on the excessive RCT portion of the listing, base level managers should determine what actions are necessary, if any, to reduce AWP impact on the RCT. Separate statistics for RCT and average AWP time should be provided to facilitate this determination. Average AWP time statistics would provide an initial point for identifying EOQ items that require minimum levels in order to reduce AWP time.

Summary statistics should then be computed by ERRCD on the number of items with excessive RCT, including AWP time, and the percent of recoverable items with excessive RCT, including AWP time. Items with exception repair cycle days sufficient to bring expected performance up to the implied level would not be included in the calculations. A separate total and percentage would be computed for items with sufficient exception repair cycle days.

A management indicator should be provided on the "Monthly Base Supply Management Report." This indicator should be a restatement of the summary statistics from the "Repair Cycle Data List," i.e., the overall statistics of the percentage of stocked items by ERRCD with an RCT, including AWP time, which are downgrading performance.

NCT

A management indicator for NCT should mirror RCT. Since data for NCT are not presently captured, programs should be written to capture them. The "Repair Cycle Data List" should be altered to include NCT data. Either the present standard of two days or a more realistic standard should be used to identify items with excessive NCT. Items having NCTs excessive enough to reduce expected performance below that which could be expected if standard NCT was achieved or below the implied performance level, whichever is lower, should be listed.

An exception NRTS time should be developed and provided for items that cannot be processed in the standard NRTS time. Those items qualifying for exception NRTS time should be identified. The remaining items should then be examined to determine the actions required to bring the items within standard. As with RCT, AWP time should also be tracked and a separate average for AWP time should be

listed. The AWP procedures applied to RCT should also be applied to NCT.

Summary statistics should be computed for NCT by ERRCD. The statistics developed for RCT should be used for NCT and the same indicators should be developed and listed in the "Monthly Base Supply Management Report."

The procedures employed in developing EOQ item indicators for O&ST, financial restrictions, and releveling should be employed in the development of indicators for recoverable items.

Recommended Engine Model Indicators

Base level managers should be provided with the values of the engine model variables, the expected performance level based on current variable values, and the expected number of time-weighted backorders so that they can assess the risk associated with their decisions. Since a backorder can be expected to place an aircraft in NORM or NORS status, it is particularly important that decision-making information be available and management decisions carefully weighed.

Since base level managers are responsible for the Receive Trans Start Work and Buildup (In Work) segments of base ARBUT, the values of those segments should be provided separately from the depot ARBUT information.

As discussed in the background for this thesis, it is important that standards be both reasonable and related to operational performance. A recent SAC study has questioned the current resupply time standards:

> The initial problem appears when comparing pipeline times reported by base level with AFM 400-1 standards. The reported pipelines, found in D024 products, are often two to three times the standards in AFM 400-1.
>
> . . . AFM 400-1 states that the ". . . standards established are the average times (in elasped [sic] calendar days) that should be realized in each segment of the engine pipeline. . . ." Since reported pipeline times far exceed the standards, it became apparent that the engine standards are not "averages" of the normal peacetime (reported in D024) work flow. They are perhaps averages of wartime standards. . . [37:1,9].

HQ USAF should evaluate the present AFM 400-1 pipeline standards. If these standards are to be meaningful, they must be realistic for the peacetime environment. If resources currently available to base level and AFLC managers are sufficient to achieve these standards, the reasons for the discrepancies between performance and expectation should be identified. If these standards are not appropriate, they should be replaced with standards that are appropriate. A balance should be found between the resources available for the peacetime environment and the capability needed for a wartime surge (37:14-15).

Additionally, while AFM 400-1 prohibits the use of work stoppage time due to lack of parts for Engine NORS

(ENORS) in computing spare engine levels, the effects of ENORS on performance should not be disregarded (45:7-1). The above-mentioned SAC study states:

> Pinpointing ENORS as a problem would allow more efficient focus on problems with parts, thus enabling more concentration on corrective actions when this becomes the major constraint.
>
> . . . Approximately 15% of all ARBUT engines and 25% of all base maintenance engines are delayed by ENORS. In terms of an average delay for all engines, ARBUT engines experience one day of ENORS and base maintenance engines experience five days of ENORS [37:3,14].

The primary indicator for the engine model should be the expected performance level. This indicator should be compared to the implied performance level to ensure the system is meeting USAF objectives. Additional indicators should be: Base Repair Cycle Days (Net of ENORS), Base Repair Cycle Days (Including ENORS), Base ARBUT Segment (Net of ENORS), Base ARBUT Segment (Including ENORS), and Depot ARBUT.

The proposed indicators, along with the values of the remaining variables, OHRI and BMRI, will allow base managers to better assess risk and to make more intelligent and effective decisions. Information as to system performance should be available to base level managers as well as to managers at higher levels. If a base does not have the skilled personnel available to calculate the risks involved in decisions involving variable values, a

capability should be created to provide the information to the base as a matter of routine.

Conclusions

Although a management indicator that directly measures the relationship between supply system performance and operational capability cannot be developed, the proposed indicators provide workable surrogates. Additionally, the proposed indicators are calculable from system variables. The proposed management indicators provide the necessary tools to evaluate and control base level supply system performance. While the use of the proposed indicators will require some programming changes, basic USAF inventory policy will not have to be changed. In fact, this method for identifying supply system indicators is insensitive to the inventory policy used. The point is that by identifying a system's variables, the constraints placed on the variables, and the system's implied performance level, management indicators can be developed that identify items whose expected performance level is less than the implied level and can identify the cause. Management can then either take the necessary action to bring the variables within their constraints or accept the risk associated with the expected performance level.

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